By James R. Valdes, WA1GPO

The FARA HF Project

Would you like an economical and relatively easy to build 30 W HF amplifier? For about $130 worth of parts you can give that QRP rig an extra 12 dB of muscle!

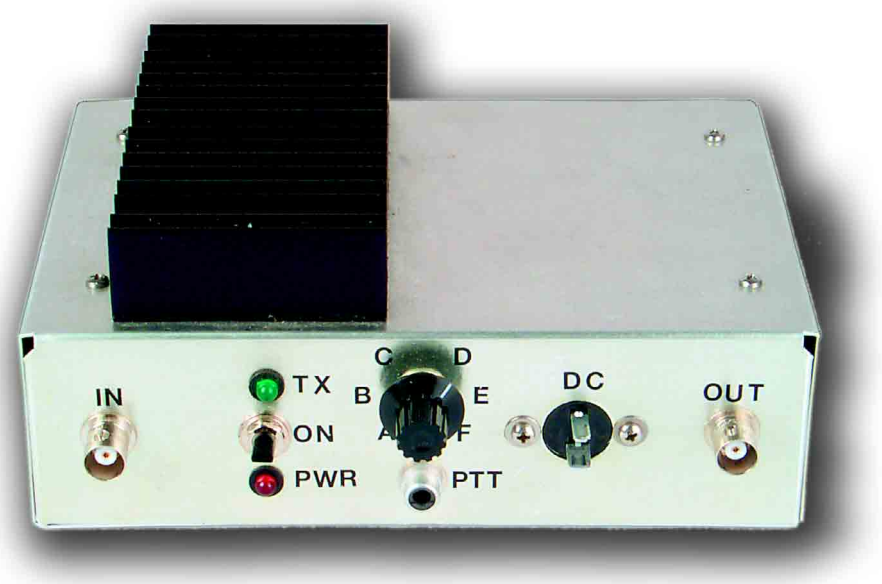

Figure 1—The completed 30 W amplifier. The band switch takes care of output low-pass filter switching.

One of the larger and more active radio clubs in the Cape Cod, Massachusetts area is the Falmouth Amateur Radio Association (FARA). Some of its members are affectionately referred to as the "hackers"—those who enjoy the construction phase of Amateur Radio. The renewed interest in low power (QRP) radios in the 2 to 5 W output range resulted in the desire for a 10 to 12 dB gain RF linear amplifier producing 30 to 40 W of output power. Commercial amplifiers capable of being driven with less than 50 W below 30 MHz are prohibited by FCC regulations.[1] As a radio amateur, you are permitted to construct one amplifier per year for your personal use. The amplifier described here is relatively easy to fabricate, given a basic knowledge of electronics and some familiarity with hand tools. This article describes in detail the construction of a 12 dB, nominal 30 W output, 1.8 to 30 MHz RF power amplifier. It is intended for 12 to 14.7 V dc operation, making it ideal for mobile use.

Amplifier Description

The design of the amplifier is based upon common engineering practices. Ideas gathered from researching the handbooks published by the ARRL and The Radio Society of Great Britain (RSGB), as well as articles published in *QST* and other journals formed the basis of the design. This amplifier uses readily available components…many of the earlier designs were based on the Motorola MRF series of RF devices that are no longer available or are prohibitively expensive.

The amplifier is housed in a 5 × 7 × 2 inch aluminum box. It consists of two stacked circuit boards—an RF amplifier and a low-pass filter. The completed amplifier is shown in Figure 1. Figure 2 is the schematic diagram of the RF assembly together with the amplifier and low-pass filter parts list and Figure 3 is the low-pass filter schematic. The amplifier can be driven by 2 to 5 W at the RF input; an input attenuator consisting of R1, R2 and R3 must be selected (as noted in Figure 2) to ensure the proper drive level (2 W) for the push-pull (2SC2312C device types) class AB amplifier stage. T1 is wound on a small binocular core with a 4:1 ratio as detailed on the schematic. The low impedance secondary is a single turn center tapped; it carries the bias voltage to the output transistors. The bias voltage is derived from the LM317 regulator, which is operated as a switched current source. The LM317 is switched on when the internal PTT line is activated. Bias voltage is developed across the FES8J diode, which is in intimate thermal contact with the output transistors. The output transformer (T2) is also wound with a 4:1 ratio; it has a single-turn sense winding. The single-turn feedback winding provides some degree of negative feedback to flatten the gain and stabilize the input impedance over the HF frequency range. The RC network in the input base circuit establishes the overall gain. The 6.8 Ω series resistors determine the gain below 14 MHz, while the 4700 pF capacitors are effective above 14 MHz.

Figure 4 shows the output power versus frequency characteristics of the amplifier, including the second and third harmonic response. All measurements were made with an IFR1600S Communications Service Monitor. In all cases, harmonics were greater than 40 dB down referenced to the fundamental frequency (–40 dBc), and the amplifier meets current FCC requirements for spectral purity.[2] Note that the gain starts to decrease above 21 MHz, rolling off from a nominal 30 W to 20 W at 29 MHz. On 10 meters this still represents 10 dB of gain, a worthwhile improvement. The dc voltage to the output transistors is decoupled by the pi network at the center-tapped

[1]Notes appear on page 39.

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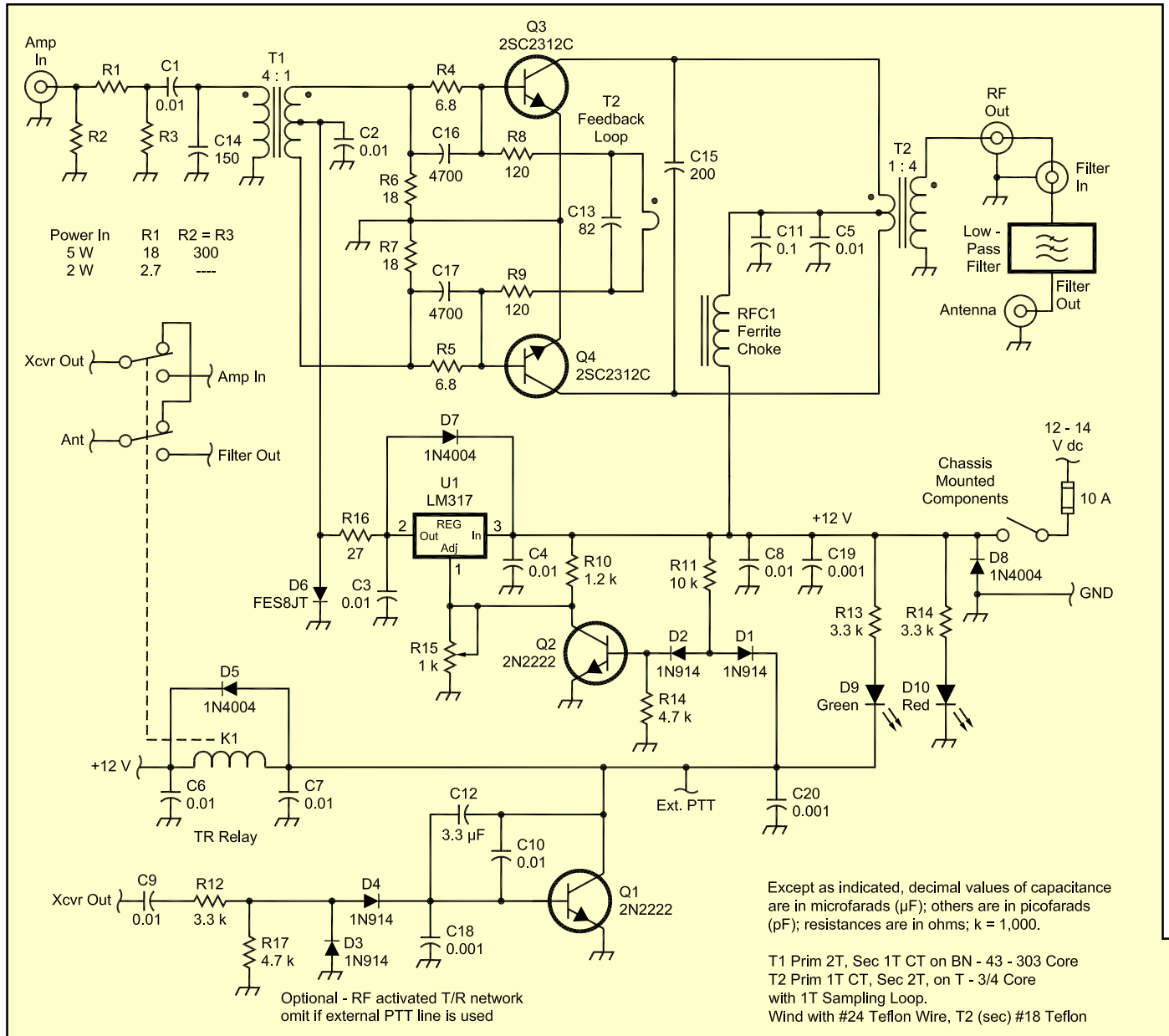


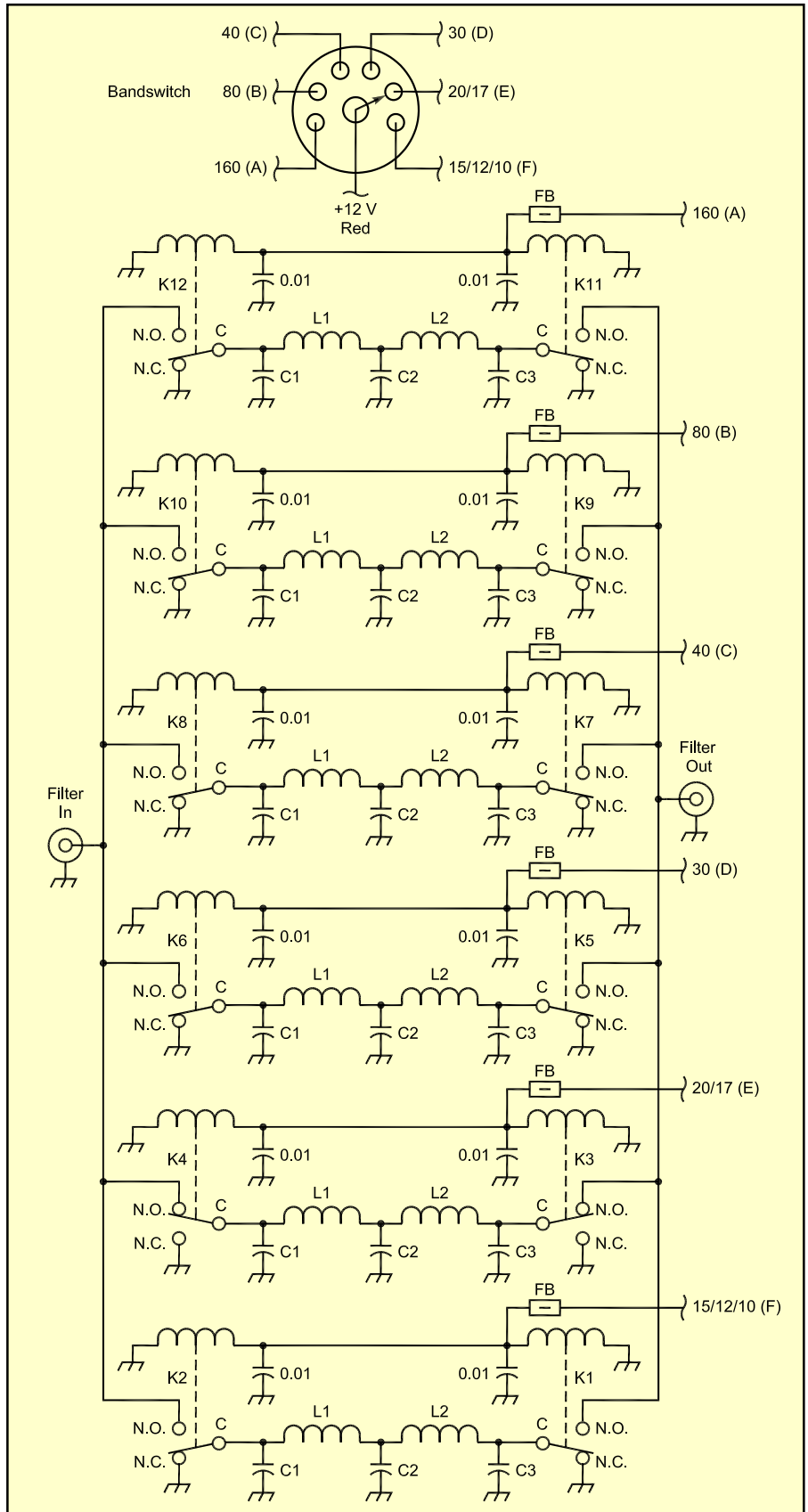
Figure 2—The RF amplifier schematic and parts list. (M) denotes Mouser Electronics, 1000 N Main St, Mansfield, TX 76063; tel 800-346-6873; www.mouser.com. (RF) denotes RF Parts Co, 435 S Pacific St, San Marcos, CA 92069; tel 800-737-2787; www.rfparts.com. (A) denotes Amidon, Inc, 240 Briggs Ave, Costa Mesa, CA 92626; tel 800-898-1883; www.amidon-inductive.com. (F) denotes FAR Circuits, 18N640 Field Ct, Dundee, IL 60118; tel 847-836-9148; www.farcircuits.net.

RF Amplifier Board
C1-10—0.01 µF capacitor, (M) 140-100Z5-103Z.
C11—0.1 µF capacitor, (M) 80-CK06BX104K.
C12—3.3 µF capacitor, (M) 80-C340C335M5U.
C13—82 pF capacitor, (M) 5982-15-500V82.
C14—150 pF capacitor, (M) 5982-15-500V150.
C15—200 pF capacitor, (M) 5982-15-500V200.
C16, 17—4700 pF capacitor, (M) 140-50P5-472K-TB.
C18-20—0.001 µF capacitor, (M) 140-100Z5-102Z.
D1-D4—1N914 diode, (M) 610-1N914.
D5, D7, D8—1N4004 diode, (M) 583-1N4004.
D6—FES8JT diode, (M) 625-FES8JT.
D9—LED, green, with mount, (M) 512-HLMP4719.
D10—LED, red, with mount, (M) 512-HLMP4700.
K1—Relay, 12 V dc coil, DPDT, (M) 551-MR-12USR.
Q1, Q2—Transistor, switching, 2N2222, (M) 511-2N2222A.
Q3, Q4—Transistor, RF, 2SC2312C, (RF) 2SC2312C.
R1—300 Ω, 1 W, (M) 281-300.
R2, R3—18 Ω, 1 W, (M) 281-18.
R4, R5—6.8 Ω, ¼ W, (M) 30BJ250-6.8.
R6, R7—18 Ω, ¼ W, (M) 30BJ250-18.
R8, R9—120 Ω, ¼ W, (M) 30BY250-120.
R10—1.2 kΩ, ¼ W, (M) 30BJ250-1.2K.
R11—10 kΩ, ¼ W, (M) 30BJ250-10K.
R12-14—3.3 kΩ, ¼ W, (M) 30BJ250-3.3K.
R15—1 kΩ, potentiometer, (M) 531-PTC10H-1K.
R16—27 Ω, 1 W, (M) 281-27.
R17—4.7 kΩ, ¼ W, (M) 30BJ250-4.7K.
RFC1—RF choke, (RF) VK-200-3R.
T1—Transformer core, (A) BN-43-303.
T2—Transformer core, (RF) T-¾ core.
U1—IC, LM317T, (M) 512-LM317T.

Misc
2—TO-220 mounting kit, (M) 534-4724.
2—TO-220 thermal insulator pad, (M) 526-NTETP0006.
PC board, FARA RF amplifier, (F).

Low-Pass Filter Board
(see Figure 3 for component delineation)
2—100 pF capacitor, (M) 5982-15-500V100.
3—180 pF capacitor, (M) 5982-15-500V180.
3—330 pF capacitor, (M) 5982-15-500V330.
2—430 pF capacitor, (M) 5982-15-500V430.
1—560 pF capacitor, (M) 5982-15-500V560.
3—820 pF capacitor, (M) 5982-15-500V820.
3—1500 pF capacitor, (M) 5982-19-500V1500.

Figure 3—The low pass filter (LPF) schematic.



Cores T - 50 - X Amidon
L in number of turns (#22)
C in pF
Band (E) Shown Selected.
K3, K4 Energized.

Band	L1/2	C1/3	C2	Core
160 (A)	30	1500	2700	2
80 (B)	22	820	1500	2
40 (C)	16	430	820	2
30 (D)	14	330	560	2
20 - 17 (E)	11	180	330	6
15 - 10 (F)	8	100	180	6

primary of the output transformer, T2. This winding carries substantial current and should be wound with #18 Teflon covered wire. Any IR drop in the dc circuit will severely degrade the amplifier performance. TR switching is provided by relay K1. The PTT line can be operated manually (pulled to ground) or RF activated switching circuitry can be installed to eliminate the need for external keying controls. The value of C12 (3.3 µF) determines the SSB time constant for the RF activated switch.

The low-pass filter assembly utilizes relays to select the proper filter network for the various frequency ranges. Relays were chosen to simplify the RF switching and to minimize cost. The six filters cover the nine amateur bands from 1.8 to 30 MHz; the frequency ranges and circuit constants are as noted on the LPF schematic diagram. The inductor cores and wire to wind the coils are available as a kit of parts from Amidon.[3] The L/C constants are the same as those recommended by WA2EBY for the MOSFET RF amplifier in *The ARRL Handbook*.[4] The filters are not used when the amplifier is off or when the PTT line is not activated—this permits multi-band listening and limited VHF use when a wide frequency transceiver is in use (like the Yaesu FT-817). There is no provision for ALC feedback, so

1—2700 pF capacitor, (M) 5982-19-500V2700.
12—0.01 µF capacitor, (M) 140-100Z5-102Z.
12—Relay, 12 V dc coil, DPDT, (M) 655-T7NS5D1-12.
1—Switch, 1 pole, 6 pos, (M) 10-YXX026.
HF Filter Kit, (A) HFFLT. Contains the cores and wire necessary to build the low-pass filters.
PC board, FARA LP Filter, (F).

Chassis Parts
Chassis box, Bud, (M) 563-AC-402.
Chassis cover, Bud, (M) 563-BPA-1589.
Heat sink, (M) 532-244609B02.
4—4-40 hex-type standoff, (M) 534-2201.
9—4-40 × ¼ pan head screw.
4—4-40 × ½ pan head screw.
6—4-40 flat washer.
9—4-40 lock washer.
2—4-40 nut.
2—8-32 × ¼ pan head screw.
2—8-32 lock washer.
2—BNC socket, chassis mount, (M) 161-9323.
RCA-type socket, female, chassis mount, (M) 161-1005.
Switch, toggle, SPDT, (M) 10TC320.
Jones-type socket, chassis mount, male, 2 pin, polarized, (M) 538-13023.

caution must be exercised so as not to overdrive the amplifier.

Construction Hints

Although no step-by-step instructions are provided, a few hints will ease the assembly process. The circuit boards pictured are the prototype assemblies; they are not solder-plated. However, the available circuit boards (from FAR Circuits) are plated but do not have plated through-holes, so through-holes must be pinned and soldered.[5] Detailed drawings of the PC boards, the parts layout, coil-winding data and chassis templates can be found at **www.arrl.org/files/qst-binaries/fara-amp.zip**. Saul, K1BI, the FARA Webmaster has also set up a site for the project. It can be found at **www.falara.org/tektalk/tektalkfs.html**.The circuit boards as they appear before wiring can be seen in Figure 5.

Circuit Board Preparation

• Given the large ground plane area, the boards must be clean or you will experience difficulty when soldering to the foil. Plated boards are best; they are easier to solder. Some solder flux may improve the solderability of the board, but be sure to use *only* rosin core solder and a *non-corrosive* flux.

• Carefully inspect all soldered connections for cold solder joints. Good soldering technique is crucial to the performance of the amplifier.

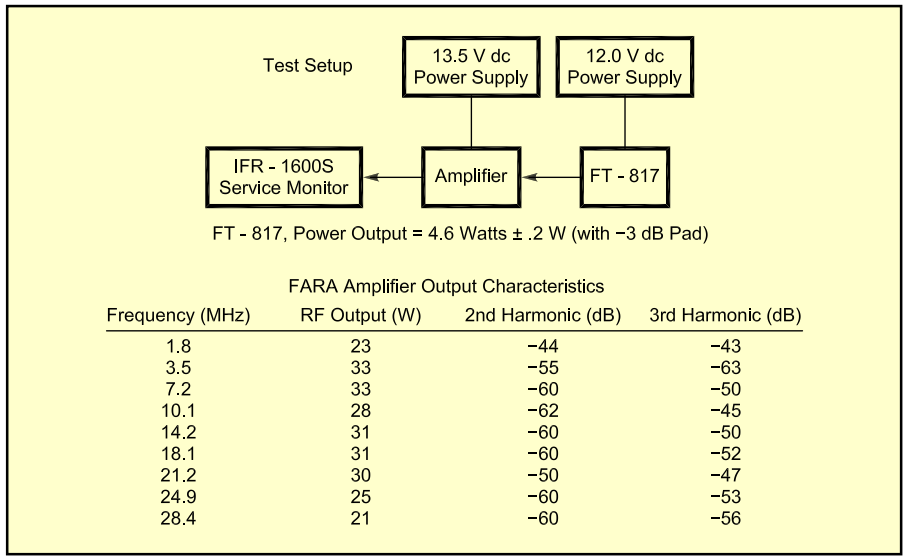
• Periodically, the flux should be removed from the board during the construction phase with a suitable chemical cleaner.

• There are a number of holes to be drilled and pinned on each board; these are noted on the parts placements diagrams. Wires should be inserted through the board, bent into the shape of a "Z," formed flat against the board, soldered and cut.

• The four corner holes on each board must be sized as a clearance hole for the 4-40 mounting hardware.

• Components should be mounted flush to the board––fixed capacitors should be mounted as close to the foil as possible.

• The large rectangular blocks on the RF board must be trimmed in order to mount the RF output transistors and the bias diode.



FT - 817, Power Output = 4.6 Watts ± .2 W (with −3 dB Pad)

FARA Amplifier Output Characteristics

Frequency (MHz)	RF Output (W)	2nd Harmonic (dB)	3rd Harmonic (dB)
1.8	23	−44	−43
3.5	33	−55	−63
7.2	33	−60	−50
10.1	28	−62	−45
14.2	31	−60	−50
18.1	31	−60	−52
21.2	30	−50	−47
24.9	25	−60	−53
28.4	21	−60	−56

Figure 4—Amplifier output data, including second and third harmonic response.

RF Amplifier Circuit Board

A view of the completed RF board can be seen in Figure 6. The following suggestions pertain to the amplifier board.

• Wind the secondary winding on T2

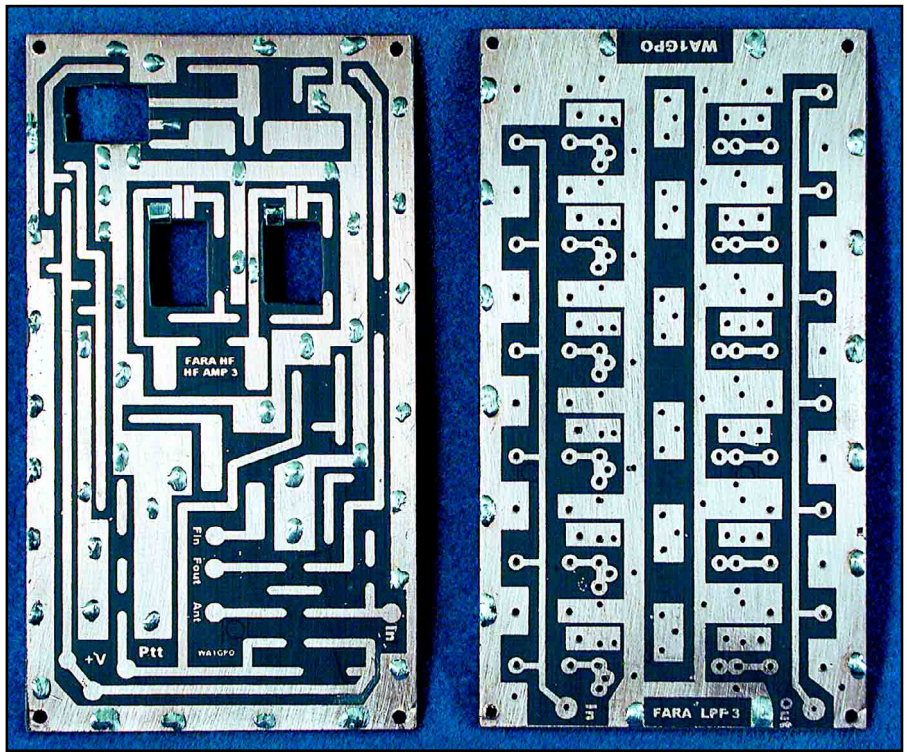


Figure 5—The circuit boards before wiring. The RF board is on the left and the LPF board is to the right. Note the pinned and soldered holes.

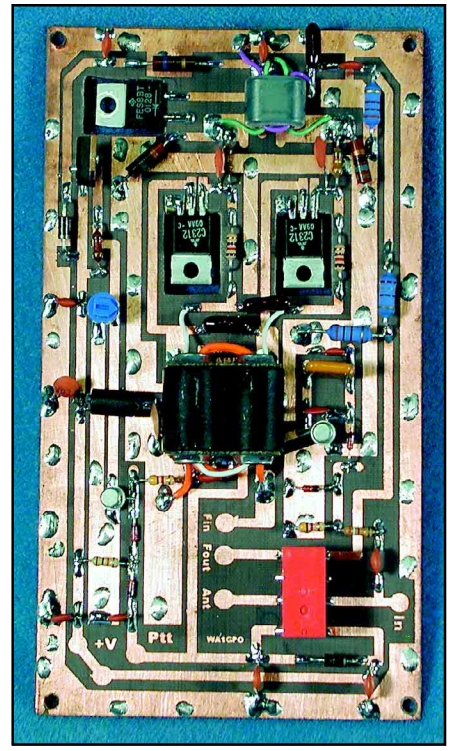


Figure 6—The completed RF assembly board.

and mount it to the circuit board first.

• The emitters of the 2SC2312s (Q3, Q4) are intended to be grounded through a hole on the pad. The following modification is advised—bend a thin brass or copper strap into a "U" shape and solder it on both sides of the board. This lowers the impedance to ground.

• Next, mount the smaller fixed components, the resistors and capacitors.

• The semiconductors and the relay mount last.

• Do not mount D6, Q3 and Q4 until the assembly is fixed in the chassis and positioned relative to the heat sink.

Low-Pass Filter Circuit Board

This is a double-sided board; the reverse side is a ground plane with clearance etches for the various components. The LPF board can be seen in Figure 7. It may be necessary to form the capacitor leads slightly to conform to the hole spacing.

• Mount the filter components first, followed by the bypass capacitors and the jumper wires. Refer to the schematic for component values by frequency range.

• The relays mount last. Do not overheat their mounting pins when soldering.

• Do not mount the LPF assembly until the initial tune-up is completed. It is recommended that you pre-wire the band switch. It mounts between the two circuit boards when they are installed in the chassis and it is difficult to get to.

Chassis, Panel and Heat Sink

Full size templates for the chassis and panel can be found on the Web site. Trim the templates to size and fold and tape them to the aluminum box and heat sink. It is important to center punch the holes and drill a small pilot hole at each location. Enlarge the holes to size according to the dimensions. Letter the panel with dry transfer lettering available at office supply stores. Spray on several light coats of clear lacquer to protect the lettering. Mount the heat sink and the panel components, but do not mount the bandswitch at this time. Mount the RF amplifier board using a couple of 4-40 flat washers as spacers between the chassis and the circuit board at each corner. Install the 4-40 standoffs to hold the assembly in place. Mount D6, Q3 and Q4, using the TO-220 thermal pads and hardware to isolate the transistor mounting tab from the chassis. It is not necessary to isolate D6. Use RG-174 miniature coaxial cable for the internal RF connections.

Tune-up and Testing

As this is a broadband design there is no tune-up; only the bias adjustment needs to be set. A 12 to 14 V dc current limited variable supply is recommended for initial adjustment and testing. Use a dummy load at the amplifier output. Drive levels refer to the attenuator output, if used.

• Connect a temporary jumper between the F_{in} and F_{out} pads on the RF board.

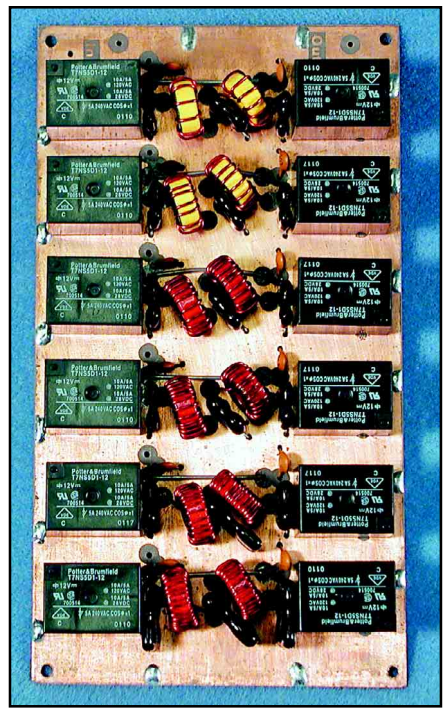


Figure 7—The completed LPF board. Note the relays that are used as filter switches—they are selected by the band switch.

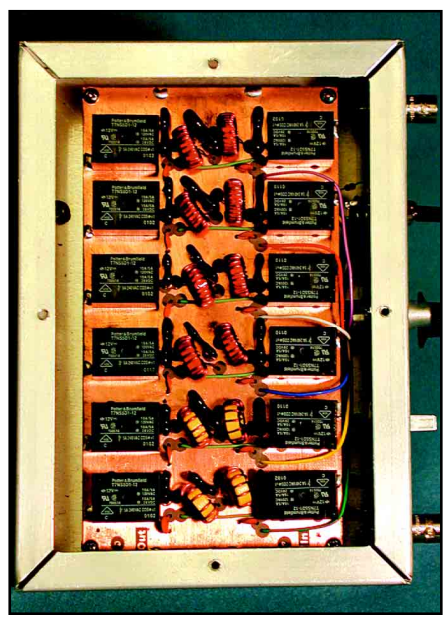


Figure 8—A bottom view inside the completed amplifier. The LPF board is mounted below the RF assembly.

• Preset R15 (1 kΩ potentiometer) so that the wiper is at ground.

• Apply 12 V dc and ground the PTT line (the relay should pull in).

• Briefly drive the input with 1 W at 14 MHz and note the power output.

• Again apply 1 W and increase bias (R15) until the output increases about 15%.

• Increase drive to 2 W and note the power output (about 25 W).

• Increase voltage to 14.7 V dc; note the output with 2 W of drive (about 35 W).

Remove power; remove the temporary jumper; mount the band switch; connect and install the LPF board. Verify that the power output over the range of 1.8 to 29 MHz is as expected. A view inside the bottom of the amplifier, with the LPF board visible, is shown in Figure 8.

Final Comments

The FCC has placed strict limitations on power amplifiers used below 30 MHz. Please review the appropriate FCC regulations before constructing this amplifier.[6] Kits offered for sale, even partial amplifier kits that require additional parts, are prohibited by current FCC regulations.[7]

Construction time, assuming that all the components are on hand and the boards are properly prepared, is about 4 hours. SSB operation results in the heat sink barely getting warm, and cooling under key-down conditions is more than adequate.

A project of this scope is more fun when others participate. Harry, W2RKB, provided the necessary prodding to get it started. He also fabricated the circuit boards and the filter assemblies for the prototype amplifiers. Dave Hosom assisted with the photographs. A generous thank you is extended to them both. Give the FARA amplifier a try… it's a practical and rewarding project!

Notes

[1]Federal Communications Commission, Sec 97.315.
[2]See Note 1.
[3]Amidon Associates, Inc, 240 Briggs Ave, Costa Mesa, CA 92626; 800-898-1883; **www.amidon-inductive.com**.
[4]*The 2003 ARRL Handbook*, pp 17.91-17.97.
[5]FAR Circuits, 18N640 Field Court, Dundee, IL 60118; tel 847-836-9148; **www.farcircuits.net**.
[6]Federal Communications Commission, Sec 97.3 (19).
[7]See Note 6.

Jim Valdes, WA1GPO, has been a ham since 1962 and holds an Extra Class license. Jim is an engineer and works for the Woods Hole Oceanographic Institution. You can contact him by e-mail at **wa1gpo@arrl.net**.